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U.S. Army Aviation Test Board

US ARMY TEST AND EVALUATION COMMAND
COMMODITY SERVICE TEST PROCEDURE

LASER SYSTEMS, AIRBORNE

1. OBJECTIVE

This document provides existing test methods and techniques necessary to determine the degree to which airborne laser systems and their associated tools and test equipment (maintenance package) meet the requirements stated in Qualitatative Materiel Requirements (QMR's), Small Development Requirements (SDR's), or Technical Characteristics (TC's, and whether or not the system is suitable for Army use.

2. BACKGROUND

a. The laser (light amplification by the stimulated emission of radiation) is an electro-optical device first demonstrated in 1960. Lasers are characterized by their ability to emit a narrow beam of intense, coherent, monochromatic radiation and are available for use at many different frequencies including ultraviolet, infrared, and the visible. Since the first laser, extensive research has been conducted and at the present time many different types of lasers have been developed. From a theoretical standpoint, all lasers utilize the same basic physical principles, however, from the design or component aspect there is considerable variance. An individual laser may be characterized by four basic considerations; input or excitation means, laser material, operating requirements, and output. Here again there are considerable variations within each of these. The following table lists typical variations.

Table 1. Laser Variations

Excitation	Lasing Material	Operating Characteristics	Output
Optically pumped	Solid (ruby, doped glass)	Efficiency	Frequency (CW)
Electrical current	Gases	Life	Pulse rate
	Liquids	Required	Power
Junction electron	Solid semi conductor	environment	Coherence
flow in semi			Beam width and
conductors			divergence
			Pulse width

b. Present day applications and research on lasers are centered in basically four areas as follows:

1) Material working-cutting, drilling.
2) Metrology-measuring, aligning.
3) Recording/Holography.
4) Communications.

Of these, only 1) is not of interest in so far as they would be applied toward development of systems for use on Army aircraft. Research in these two areas has, however, opened the way for many new and varied applications in the field of airborne systems and the following list gives the various possible applications in the four major areas of interest with regard to Army aircraft.

5)	Flight Procedures	terrain mapping and avoidance altitude determination navigation, Doppler ranging approach alignment
6)	Surveillance/ Observation	illumination for spotting, tracking by ground forces or other aircraft.
7)	Communications	point to point, (air-to-air and air-to-ground), secure highly directive communications.
8)	Tactical Procedures	illumination for directing weapon fire and guidance of projectiles, targeting.

c. Two possibilities exist with respect to the use of laser systems on military aircraft. First, lasers can be used in applications where no capability has existed before (because of their unique properties, e.g., beam directivity) and secondly, they may be used as a substitute for existing systems. Testing for the first type of application will concentrate on examining the system performance dependent upon unique laser properties. The evaluation of the laser as a substitute system is however, complicated by the fact that the laser must not only provide equal or greater capability but must accomplish its mission without lowering reliability, increasing maintenance or requiring an unreasonable operating environment. Testing, to determine relative advantages will be carried out on a comparative basis. Evaluation of the laser system, regardless of the application, must primarily ensure that the system meets its application requirements and that the aser used is proper and has been optimally selected for the application.

d. Reliability of the laser system is also extremely important and must be maintained in the various environments (mechanical, atmospheric

changes, electromagnetic) to which it is exposed while the aircraft is engaged in the normal flight procedures utilized in training and mission operations. Other factors, such as flexible installation and physical characteristics rendering the laser system suitable for use in different aircraft, will also be examined. The total testing program shall verify the suitability of the device for use by the Army.

3. REQUIRED SUPPORT

3.1 FACILITIES

a. Avionics maintenance facility.
b. Flight test ranges which include various types of terrains.
c. Radio communications network.
d. Availability of a meteorological station.

3.2 EQUIPMENT

Appropriate number and type of test bed aircraft.

3.3 PERSONNEL

Personnel in appropriate numbers, of the proper MOS, grade, skill level, and with special training as required.

4. REFERENCES

A. AR 385-16, Safety: Safety for Systems, Associated Subsystems, and Equipment.
B. USATECOM Regulation 70-23, Research and Development: Equipment Performance Reports (EPRs).
C. USATECOM Regulation 70-24, Research and Development: Documenting Test Plans and Reports.
D. USATECOM Regulation 108-1, Photographic Coverage. (As implemented by USAAVNTBD Memo 108-1).
E. USATECOM Regulation 385-6, Safety: Verification of Safety of Materiel During Testing. (As implemented by USAAVNTBD Memo 385-10).
F. USATECOM Regulation 750-15, Maintenance of Supplies and Equipment: Maintenance Evaluation During Testing. (As implemented by USAAVNTBD Memo 750-2).
G. USATECOM Regulation 385-29, Laser.
H. MIL-STD-882, System Safety Program for Systems and Associated Subsystems and Equipment: Requirements For.
I. MTP 6-2-165, Lasers.
J. MTP 6-2-166, Laser Rangefinders.
K. MTP 6-3-501, Pre-Test Inspection for Service Test.
L. MTP 6-3-502, Personnel Training Requirements.
M. MTP 6-3-513, Qualitative Electromagnetic Interference.
N. MTP 7-3-500, Physical Characteristics.

O. MTP 7-3-502, Installation Characteristics.
P. MTP 7-3-506, Safety.
Q. MTP 7-3-507, Maintenance.
R. MTP 7-3-508, Reliability.
S. MTP 7-3-509, Compatibility with Related Equipment.
T. MTP 7-3-510, Human Factors.
U. MTP 7-3-515, Photographic Coverage.
V. TB MED 279, Control of Hazards to Health from Laser Radiation.
W. QMR, SDR or TC's for the laser system.
X. USATECOM Memo, Laser Safety Primer, 10 December 1969.
Y. MIL-STD-454B, Standard General Requirement for Electrical Equipment.

5. SCOPE

5.1 SUMMARY

This document provides existing procedures for evaluating the characteristics of laser systems installed on Army aircraft. The procedures comprising the total testing program are summarized in the following paragraphs.

5.1.1 Preparation for Test

This section provides guidance for test project planning including procedures for the training of test personnel.

5.1.2 Test Conduct

The procedures to be utilized in conducting the individual tests are given in this section. The following tests will be conducted on aircraft laser systems.

a. Inspection - A series of preliminary tests to determine that the laser system is in satisfactory condition prior to the operational tests.

b. Installation - An evaluation of installation requirements including placement and removal procedures, stability of mounting, and flexibility for use on various aircraft.

c. Operation and Performance - A determination of the operation and performance characteristics of the laser system under conditions that most nearly simulate those expected to be encountered in the field.

d. Maintenance - An evaluation of the device's maintenance characteristics and the maintenance package through examination of maintainability, reliability, and availability. This evaluation is to determine through examination of the design, maintenance procedures, tools, literature, etc., the ease with which the laser system can be maintained at, or be returned to, operative condition. Analysis of failures is also included.

e. Compatibility - An evaluation of the effects and interactions of the laser system with the established configuration of the aircraft and its mission profiles. This is a measure of the degree to which requirements for the instrument differ from, require special considerations for, or interfere with tactical procedures, equipment, tools, and materials.

f. Draft Technical Manuals - An examination of the contents of draft technical literature to determine accuracy, completeness, prescribed format, and clarity.

g. Safety - An evaluation which identifies and examines hazardous characteristics of the design, operating procedures of the laser, and maintenance; the objective is to eliminate personnel injury, materiel failures, malfunctions, and equipment losses.

h. Human Factors - An evaluation to determine the adequacy of design and performance characteristics in terms of compatibility with specified user personnel in the operational environment. Characteristics as related to human factors and revealed during the conduct of each test shall be examined.

i. Personnel and Training Requirements - An evaluation which, through observation of personnel involved in operation and maintenance procedures, will be utilized to determine the adequacy and sufficiency of training and appropriateness of skill levels and experience specified for the selected test personnel.

5.1.3 Test Data

This section details the data to be collected and recorded while completing the test procedures in paragraph 6.2, Test Conduct.

5.1.4 Data Reduction and Presentation

This section provides instructions for evaluating and displaying the data recorded during testing.

5.2 LIMITATIONS

This MTP is intended to be used as a basic guide in preparing test plans for the subject equipment. The procedures specified are applicable for the service test evaluation of aircraft laser systems. Since the applications for laser systems cover such a wide range, the operation and performance procedures have been presented in a general way so as to allow for satisfactory evaluation of systems in all applications. Also, the pertinent QMR, SDR, TC's and other applicable documents will be utilized to derive test criteria and to formulate test conditions.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Test Planning

Utilize reference 4.C to formulate the plan of test. Certain general procedures to be followed in the generation of a test plan follow:

a. Review the test directive to determine test objectives.

b. Determine criteria for the tests by reviewing QMR's, SDR's, and TC's for the system to be tested and other applicable sources containing test criteria germane to the system.

c. Become familiar with the system's technical and operational characteristics.

d. Prepare a detailed test schedule showing proposed time periods allotted for each test listed in section 5.1.2. Where possible, allow sufficient time to evaluate durability and reliability characteristics.

e. Plan to use photographic techniques where possible to record and document findings and results of testing. References4.D and 4.U shall be consulted for procedures.

f. Incorporate the proper safety precautions into all test procedures and secure any specified special safety devices required for personnel involved in testing, e.g., laser goggles, (references 4.G and 4.V).

6.1.2 Support

Review the support requirements of section 3. and any additional support determined while ascertaining test criteria. Analyze these requirements with respect to availability and scheduling.

6.1.3 Personnel

a. Select test personnel of the proper MOS with varying skill levels and backgrounds for the determination of optimum user and maintenance types.

b. Train test personnel to operate and maintain the equipment using the draft literature.

c. Determine personnel qualifications in accordance with the requirements of reference 4.L; in particular ensure that test personnel are aware of test objectives and knowledgeable in the procedures and safety precautions to be utilized.

6.2. TEST CONDUCT

6.2.1 Inspection

6.2.1.1 Inventory Check and Visual Inspection

Perform the following:

a. An inventory check against the Basic Issue Item List (BIIL), submitting an Equipment Performance Report for each noted shortage or discrepancy in accordance with the provisions of reference 4.B.

b. Pretest inspection procedures required by reference 4.K; in particular-

1) Visually inspect for defects.
2) Remove all preservatives.
3) Verify lubrication required.
4) Check for completeness of assembly.

6.2.1.2 Physical Characteristics

NOTE: Generally, do not test for data obtained and verified during the Engineering Test.

Physical characteristics shall be determined by performing the applicable sections of reference 4.N, in particular the following:

a. Note the legibility and effectiveness of markings, legends, etc.

b. Determine the dimensions, weight, and volume of all assembly components.

c. Compute the system's total weight and volume.

6.2.1.3 Technical Characteristics

Examine the following technical properties (where applicable) utilizing a bench test set-up if required.

a. Power requirements - Verify power input circuitry and measure the electrical power requirements of the system. Ensure that all requirements are satisfied by the electrical power available on the types of aircraft on which the test item will be utilized and that equipment power requirements do not exceed the allowable limits. Check also that the system operates satisfactorily over the range specified in supply voltages by varying the supplies and noting performance.

b. Controls, adjustments and indicators (mechanical and electrical) - Determine the following as appropriate:

1) Operation is correct.
2) Effect on the system is as required.
3) Absence of binding, rubbing.
4) Calibration is proper.
5) Changes are monitored and displayed correctly.
6) Range and sensitivity are correct.
7) Any discrepancies.

Devices whose evaluation required flight conditions will be checked during the Operation and Performance Test.

c. Equipment safety and protective devices - Determine adequacy of each.

d. Fail-Safe Characteristics - Examine the system for the following:

1) Internal failure - when the system becomes inoperative because of an internal failure, operator personnel shall be made aware of the condition. Simulate failures and determine suitability of all fail-safe features.
2) Acceptance or provision of external signals - if the system accepts/provides electrical signals from/to other on-board avionics equipment, operator personnel shall be made aware of any out of limit level existing on any line. Simulate failures on each line and determine the adequacy of fail-safe indications.

e. Confidence, self-checking or integrity circuits, if any - Verify proper operation.

f. Primary Technical Characteristics - Operate the laser beam into a suitable measuring load which will allow determination of operating frequency, power, repetition rate, etc. Determine also receiver characteristics, (if applicable).

g. Cold start and warm-up - Subject the system to a minimum of three consecutive cold start power application procedures. Determine warm-up time and effects due to multiple power applications.

6.2.2 Installation

Evaluate the installation properties of the system utilizing the requirements of reference 4.0, including the following:

a. Determine the requirements (time, effort, tools, materials, personnel, instructions, etc.) for installing and removing the laser system. Record recommendations for the elimination of, minimization, or improvements to any of these requirements.

b. Examine the installed device to ensure that it is secure, protected against shock and vibration, and in general, mechanically stable.

c. Examine the laser system and its mounting requirements for use on various types of aircraft. Determine for which aircraft extensive modifications are required or those which will not accept the system.

6.2.3 Operation and Performance

6.2.3.1 Preparation and Conditions for Test

a. Check the installed system according to pre-flight procedures contained in the draft manuals.

b. Ensure that all personnel are properly equipped with laser safety devices.

6.2.3.2 Ranging

Perform the following:

a. Determine the ability of the system to provide accurate and stable distance information in a ranging application.

b. Obtained a surveyed flight course which contains suitable target of various sizes and material composition. Targets should present varying degrees of expected energy reflection.

c. Layout flight approach patterns to these targets which allow passage over other landmarks. Determine also an appropriate flight altitude such that on passage over these landmarks the slant range (true distance) to the target is known. Select the passage landmarks so that different range readings will be obtained.

d. Make approaches to each target and note the range readings as passage is made over the landmarks on approach to the target.

e. On each approach, note the following:

1) Stability of distance readout.
2) Rate of change of distance reading as related to ground speed.

f. Determine also for each of the targets, the maximum range of the system by approaching the target from beyond the range where acquisition occurs and proceeding inbound.

6.2.3.3 Targeting

Perform the following:

a. Determine the ability of the system to acquire and resolve targets of varying size, shape, material composition and spacing.

b. Select groups of land based targets, two or more targets in the group, with the following characteristics:

1) The same size, shape and material composition.
2) Varying degrees of spacing between targets in the group.

c. Prepare a flight course map which shows the distance between two targets and a ground track which would correspond to the perpendicular bisector (normal) of the straight line connecting the two targets.

d. Prepare additional straight line approaches to these targets at various angles with respect to the "normal" track used in procedure c. Determine the difference in distance of the two targets to the approaching aircraft. Note that the difference in distance is equal to zero for a normal approach and equal to the true target spacing for an inline approach.

e. Perform each of the target in-bound flight procedures programmed starting with the normal approach first to determine that resolution is possible and at what distance it occurs. Resolution shall be considered achieved at each angular approach when the range difference (determined in procedure d.) of the two targets is achieved.

f. For each flight conducted, note the angle of approach, airspeed, resolution distance, actual target difference; indicated target distances at resolution and general system performance.

6.2.3.4 Communications

Perform the following:

a. Determine the capability of the system to perform a communications function.

b. Operate the airborne laser in communications with both ground positions and other aircraft in flight.

c. Conduct initial tests under ideal weather conditions.

d. Conduct single communications exercises inducing the transmission of voice or data transmission (dependent on system capability).

e. Determine for each of the tests the-

1) Ability to acquire and maintain station lock.
2) Errors in data messages.

3) Problems with voice communications such as fading, intermittance, loss of transmission, unintelligible audio, etc.

f. Obtain a measure of the beam divergence at different ranges by varying the angular direction of the laser beam from that direction at which maximum alignment signal is obtained.

g. Determine the security of the point-to-point communications link by having intruder aircraft attempt to intercept a portion of the transmitted energy. Direct blockage of the laser beam by intruder aircraft shall not be allowed.

6.2.3.5 Illuminating/Pin Pointing

Perform the following:

NOTE: These tests must conform to existing safety parameters.

a. Determine the ability of the laser system to provide target direction information for armament systems.

b. Fly the aircraft equipped with the designator laser in profiles which will allow the laser beam to be directed at various targets such as-

1) Natural and man-made geographic landmarks of varying size, shape, and composition.
2) Wheeled and tracked vehicles.
3) Troop encampments.

c. Have other aircraft (simulating attack modes) equipped with appropriate sensing equipment, fly various profiles (altitude, direction, etc.) with respect to the illuminator aircraft and measure the degree of reflected energy. Acceptable levels shall be those necessary for the receiver used for weapon fire and projectile guidance systems. Attacking aircraft shall confirm proper target acquisition with illuminator aircraft.

d. Where possible, have ground forces equipped with sensing systems participate in the procedures and attempt to determine the point at which the illuminator beam is directed.

6.2.3.6 Flight Procedures (Utilizing substitute laser system)

Perform the following:

a. Determine the ability of a laser system to replace an existing airborne system providing for the same function, e.g., laser altimeter versus electronic (radar or CW altimeter).

b. For each type of system, equip the aircraft with both the laser system and the existing system providing for the same function.

c. Conduct flight procedures utilizing the existing system for reference readings.

d. Note variations between the laser system and existing system.

e. Utilize the Materiel Test Procedure written for the existing system to provide test procedures.

6.2.3.7 Effects of Atmospheric Conditions

Selected Operation and Performance tests shall be performed during periods when changes in atmospheric conditions exist to determine their effects on system performance (transmission pattern, attenuation, sensitivity). Include tests, where possible, under the following conditions.

a. Night hours.

b. Hours at sunrise and sunset.

c. Poor weather conditions, poor visibility (rain, fog).

d. High and low temperatures existing during the test period.

e. Frontal passages with changing barometric pressures.

6.2.3.8 Durability

On completion of the Operation and Performance tests, the durability characteristics of the system will be examined. Perform the following:

a. A visual inspection with consideration given to-

1) Loose chassis components.
2) Loose or missing hardware.
3) Broken fasteners or seams.
4) Discoloration due to heat effects, rust, or corrosion.
5) Loose panel components.
6) Loose connectors or cables.

For each defect, the nature and location shall be noted.

b. A remeasurement of primary technical characteristics to determine any degradation.

c. An examination of equipment failures isolating those that are attributal to lack of durability.

6.2.4 Maintenance

a. This test is to evaluate the maintenance characteristics of

the laser system and to determine the adequacy of the maintenance package (tools, test equipment, etc.). The procedures of reference 4.Q and 4.F will be utilized with the total evaluation emphasizing the following:

1) Maintainability.
2) Reliability.
3) Tools and test equipment.
4) Technical manuscripts and draft manuals.

b. Include in the maintenance subtest the preparation of the following charts, (see reference 4.F for examples).

1) Maintenance and Reliability Analysis Chart.
2) Parts Analysis Chart.
3) Special Tools Analysis Chart.
4) Maintenance Package Literature Chart.

6.2.4.1 Maintainability

a. List and provide complete details of occurrences for scheduled maintenance without downtime and unscheduled maintenance with minimum downtime (minor adjustments).

b. List and provide complete details of occurrences for unscheduled maintenance involving downtime and/or replacement or repair of components.

6.2.4.2 Reliability

Reliability will be determined during the service test by performing the following:

a. Maintain an accurate log of the accumulated run time hours.

b. For each unscheduled maintenance involving any loss of operating time record the following:

1) Conditions which indicated the malfunction.
2) Component or feature involved and method used to determine it.
3) Damage caused to associated parts of the system by failure.
4) Repair procedures followed; personnel, material, and tools required.
5) Elapsed time since last malfunction, if any, or total accumulated run time of failing component, and time to repair failure.

c. From the times recorded, calculate the mean time between failures (MTBF) and mean time to repair (MTTR), (see reference 4.F).

d. Using the times recorded, compute the availability figures (see reference 4.F).

6.2.4.3 Tools and Test Equipment

Determine, through utilization, whether common and special tools and test equipment are suitable for the intended purpose and maintenance level and, also, whether special tools and equipment provided are excessive.

6.2.4.4 Technical Manuscripts and Draft Manuals

Perform the following:

a. Review the maintenance instructions for preventive and major maintenance procedures for accuracy and completeness.

b. Note the presence of lists of recommended repair parts, maintenance allocation charts, tools, test equipment, and procedures for alignment, calibration, and troubleshooting.

6.2.5 Compatibility

During testing, consideration should be given to compatibility of the system with the operating environment. Problems such as operational interference with adjacent electronic systems shall be determined.

Perform the following:

a. Review during all procedures the problem of compatibility.

b. Note any instances of incompatibility using the following list as a guide.

1) Preparation for Use - Note the need during installation for special tools, hardware, mounting brackets, etc. and nonstandard size or overweight items.
2) Operation and Performance - Note during the operational procedures whether or not the laser system interferes with or is itself interfered with by other on-board or ground based electronic systems. This can be accomplished by operating the system simultaneously with other on-board electrical systems and in the presence of various types of radio frequency fields generated by ground installations. Compatibility of the laser with other on-board electronic systems utilizing signals from or providing signals to the test system will be determined. The requirements of reference 4.M will also be satisfied.

6.2.6 Draft Technical Manuals

Technical manuals furnished shall provide procedures for operation and maintenance which are complete, accurate, understandable, and in the prescribed format.

Perform the following:

a. For each procedure conducted, review the applicable section of the manual(s).

b. Record any instances of literature requiring correction using the following examples as a general guide.

1) Preparation for Use - Inadequate installation or checkout procedures.
2) Operation and Performance - Instructions not sufficient to achieve proper operation.
3) Transportability - Recommendations for the handling, packaging materials, precautions not given.
4) Safety - Any required precautions not specified in the text.

6.2.7 Safety

This test is to identify and examine hazardous characteristics and features of the laser. The requirements of references 4.P, 4.E, and 4.G.

Perform the following:

a. The procedures required by reference 4.P.

b. Observe the proper safety precautions and adhere closely to the draft manual's directives which deal with safety and/or protection.

c. Examine the procedures for all tests. Report all hazards to the project officer.

d. Examine all characteristics of the laser including the procedures for its operation and maintenance to ensure that maximum safety has been provided. Consider the following:

1) Examine operating procedures with a view that improperly executed or misinterpreted instructions could result in bodily harm or equipment damage.
2) Where hazardous conditions cannot be avoided, is the item properly and conspicuously marked for the condition?

3) Are all moving parts shielded and completely enclosed?
4) Where electrical power is utilized, are the electrical circuits guarded against accidental contact?
5) Are any environmental limitations explicitly denoted?

e. Determine the adequacy of all protective and warning devices. Consider the following:

1) Overheat devices.
2) Overload protection.
3) Locking mechanisms.
4) Limit switches.
5) Visual and audible warning devices.
6) Interlocks.

NOTE: Safety confirmation shall comply with the requirements of reference 4.E.

f. Accomplish following before lasing:

1) Eye examination of operating personnel by an ophthalmologist.
2) Written SOP.
3) Designation of a laser range safety officer.
4) Orientation of all participants on laser characteristics and laser safety.
5) Procurement of laser protective eyewear.
6) Calculation of hazardous ranges for direct viewing specular and diffuse hazards.
7) Inspect range area and cause all specular material to be removed or masked.

6.2.8 Human Factors Evaluation

This evaluation is designed to determine, the degree to which design and performance, satisfy accepted standards for human factors. (reference 4.T). The evaluation will be conducted by preparing a human factors task and characteristics analysis checklist. The purpose of the checklist is to rate, from a human factors standpoint, the tasks associated with and the characteristics revealed during the procedures for preparing, operating, transporting, and maintaining the system. The rating will be either satisfactory or unsatisfactory with explantory information accompanying an unsatisfactory rating. The ratings may be made simultaneously with the above listed evaluation or separately. For all tasks/characteristics the following will be considered:

a. Ease of performance - Mental and physical effort required.

b. Support - Adequacy of instructions and tools for the task.

c. Time required - Modification of procedures to reduce time required.

d. Design characteristics - Effects on performance of tasks.

Perform the following:

e. The procedures required by reference 4.T.

f. Rate the following tasks/characteristics for the evaluation listed:

1) Preparation for Use.

a) Assemble and install.

1. Assemble components, move to installation location, place in position, make external connections, and lock into position with fasteners, connectors, etc.
2. Apply power, check controls and indicators. Make required alignment, calibrate, and adjust.

b) Note operational status.

2) Operation and Performance.

a) Controls and indicators - Operate controls, note changes in equipment status, monitor other displays.
b) Legends - Effectiveness, readibility, visibility.
c) Performance - Note correct operation and system status feedback to operator (auditory, visual, etc.).

3) Maintenance.

a) Perform preventive maintenance.

1. Clean, add lubricants.
2. Remove and replace minor items.
3. Tighten fasteners, connectors.
4. Adjust, calibrate, align.

b) Perform nonscheduled maintenance.

1. Detect malfunction by observing displays, noting visual or audible changes, or changes in operating effectiveness.
2. Isolate and identify causes by visual means or instrumentation.

c) Remove and replace.

1. Open, gain access to, and remove component.
2. Replace or repair and re-establish proper operation.

6.2.9 Personnel and Training Requirements

Perform the following:

a. Utilize personnel of varying skill levels and experience throughout the test program to determine the optimum personnel type.

b. Review the performance of personnel during the operational and maintenance procedures paying particular attention to mistakes or errors made in operational procedures anc excessively long maintenance tasks.

c. Review the effects of the training programs as to their adequacy, etc., noting also any additional training required during the test and suggestions for changes to the training program.

d. Make a quantitative estimate as to the average number of training hours required for both operational and maintenance personnel.

6.3 TEST DATA

6.3.1 Preparation for Test

6.3.2 Test Conduct

6.3.2.1 Inspection

6.3.2.1.1 Inventory Check and Visual Inspection

Record the following:

a. The data required by reference 4.K.

b. Locations and types of physical defects found.

c. Any materials missing from the Basic Issue Item List (BIIL).

6.3.2.1.2 Physical Characteristics

Record the data required by reference 4.N and the following:

a. Equipment markings which are illegible or unclear.

b. Dimension, volume, and weight data for all components and total system weight and volume.

6.3.2.1.3 Technical Characteristics

Record the following:

a. Any instances of electrical incompatibility with respect to power requirements.

b. For all controls and indicators, list beside each item any of the following conditions:

1) Improper operation.
2) Desired effect on system not indicated.
3) Binding, rubbing, jerky in motion.
4) Improper calibration.
5) Proper monitoring and display of system conditions not shown.
6) Range too small, too large, etc.

c. Any protective or safety device which does not operate properly.

d. Any evidence that the system does not meet specified fail-safe requirements.

e. Any problems encountered in the operation of self-checking or integrity circuits.

f. Any technical characteristic which fails to meet required specifications.

g. Evidence of excessive warm-up time or improper operation following power application procedures.

6.3.2.2 Installation

Record the following:

a. The data required by reference 4.0.

b. All data associated with the installation or removal of the system, on each type aircraft, and any recommendations for improvements to these requirements.

c. Any evidence that the installed system is not mechanically stable, e.g., insufficient fasteners, cables not protected, etc.

d. List each aircraft on which the system cannot be installed or to which extensive modifications are required.

6.3.2.3 Operation and Performance

6.3.2.3.1 Preparation and Conditions for Test

Record the type of laser system to be tested and the operation and performance tests to be utilized.

6.3.2.3.2 Ranging

Perform the following:

a. Prepare a detailed layout of the test course showing distances, etc.

b. For each target approach flight list the following:

1) Description of the target.
2) Range indication at each passage over a landmark.
3) Airspeed and altitudes flown.

c. Record comments for each flight on the following:

1) General stability of readings.
2) Erratic readings for a particular target.
3) Rate of change of range information as compared to airspeed.

6.3.2.3.3 Targeting

Perform the following:

a. Prepare a detailed map of the test course, showing location and distances to targets, proposed flight paths and target distance for each flight.

b. For each flight conducted, list the angular separation of the targets and the distance at which resolution occurs.

6.3.2.3.4 Communications

Perform the following:

a. Record details of each communication test performed including the following:

1) Type of test, for example, air-to-air.
2) Ranges of test and maximum range determined.
3) Ability to acquire and maintain lock.

b. Record comments on the quality of voice transmission and the qualitative error rate in non-voice transmission.

c. Record an approximate rate of beam divergence per unit of distance.

d. Record comments on the degree to which security can be violated by intruding aircraft.

6.3.2.3.5 Illuminating/Pin Pointing

Perform the following:

a. Provide complete details of all test flights including the following:

1) Location of target and direction of illuminator aircraft flight.
2) Characteristics of the target.
3) Flight procedures of the attacking aircraft and sensor readings at various positions with respect to the target.

b. Record comments concerning the general performance of the system emphasing remarks on those types of targets which are most easily acquired and locked to.

6.3.2.3.6 Flight Procedures (Substitute laser system)

Note and record any instances where readings taken from the two systems are in disagreement and record also conditions under which these instances occur.

6.3.2.3.7 Effects of Atmospheric Conditions

Record the following:

a. The various atmospheric conditions under which tests were conducted.

b. Flight procedures used.

c. Indications of equipment malfunction or loss in performance.

6.3.2.3.8 Durability

a. For the visual inspection, record the nature and location of the following:

1) Loose components, hardware, connectors.

2) Discolorations.
3) Broken or frayed components.

6.3.2.4 Maintenance Evaluation

Record the data required by reference 4.Q and complete the maintenance charts.

6.3.2.4.1 Maintainability

Record the following:

a. For each scheduled or unscheduled maintenance involving minor adjustments:

1) Operation performed.
2) Personnel, time, tools, etc., required.
3) Elapsed time since last performance of the same procedure.
4) Difficulty in using instructions provided.

b. For each unscheduled maintenance involving excessive downtime and/or replacement or repair of component, record the data as called for in 6.3.2.4.2.b.

6.3.2.4.2 Reliability

Record the following:

a. Total operating time of the system.

b. For unscheduled maintenance procedures involving downtime:

1) Failure conditions indication - loss of power, etc.
2) Failing component and procedures used to determine it.
3) Signs of damage to other components - burns, etc.
4) Repair procedures, personnel, material, tools, equipment utilized.
5) Operating time of failing component, and time to repair.

c. The reliability figure in MTBF and also MTTR.

d. Record the inherent and achieved availability figures in percentage.

6.3.2.4.3 Tools and Test Equipment

Record the following:

a. All tools and test equipment not specified but required.

b. Special tools provided but replaceable by those found in the maintenance facility complement.

c. Recommendations for changes to tools or test equipment.

6.3.2.4.4 Technical Manuscripts and Draft Manuals

Record the following:

a. Procedures which are inaccurate, incomplete or not understandable.

b. Missing lists or procedures for specific maintenance, e.g., calibration missing.

6.3.2.5 Compatibility

Record the data required by references 4.S and 4.M, and instances of the following:

a. Physical or electrical characteristics not compatible with aircraft capabilities.

b. Laser system interferes or is interfered with by other equipment generating, utilizing, or radiating electrical energy.

c. System compatibility with existing aircraft electronic equipment.

6.3.2.6 Draft Technical Manuals

Record any instances, for all test, of information which is missing, incorrect, unclear, or not according to format.

6.3.2.7 Safety

Record data required by reference 4.P and the following:

a. Comments regarding hazardous conditions found in the procedures of any test.

b. For general safety characteristics:

1) Poorly worded or unclear operating instructions.
2) Warning labels - lacking, not conspicuous.
3) Unprotected electrical circuits.
4) Markings for environmental limitation missing.

c. Prepare a table to include the following:

1) A list of all safety devices utilized.
2) The type of failure each device is to detect.
3) Indication that the device has successfully operated.

d. List any missing devices or hazardous conditions.

e. List any suggested additions to the safety features.

f. Prepare a safety confirmation statement.

6.3.2.8 Human Factors Evaluation

Record the data required by reference 4.T and in addition, complete the checklists prepared for the tasks of the procedures for preparing, operating, maintaining, and transporting the system. Rate each task as satisfactory or unsatisfactory from a human factors standpoint. In rating each task consider and record instances of the following:

a. Instructions.

1) Lacking clarity.
2) Insufficient or excessive detail.

b. Tools.

1) Proper tools not supplied.
2) Excess of special tools specified.
3) Additional tools recommended.

c. Mental and Physical Effort.

1) Above average skill or strength required of test personnel.
2) Task is excessively tiring.

d. Design.

1) Poor location of component.
2) Component not accessible.
3) Visibility hindered.
4) Adequacy of controls, adjustments, etc.

e. Time required for task is excessive and reasons why.

f. Personnel requirements.

1) Insufficient number specified.
2) Qualifications in error.

6.3.2.9 Personnel and Training Requirements

Record the following:

a. The most appropriate skill levels and experience (background) suggested for operator and maintenance personnel.

b. Any suggested changes to training techniques, literature, etc., to eliminate operator errors or reduce maintenance time.

c. Each additional training technique utilized after the start of testing and suggestion for additions or deletions to the training program.

d. The training time, in hours, for maintenance and operating personnel.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Ranging

Summarize all test data by comparing the results obtained on each of the targets. Note particularly any target for which the system performance was unsatisfactory. Compare all range readings with actual distances as given on the course map.

6.4.2 Targeting

Analyze all test data to determine the following:

a. Effect of target material and size.

b. Maximum resolving capability of the system, i.e., smallest target with minimum separation at maximum distance.

6.4.3 Communications

Analyze all test data and compare results of the test against the use of normal radio communications noting particularly the degree to which secure communication was achieved.

6.4.4 Illuminating/Pin Pointing

Review all data and summarize in table form the results obtained from testing. The table should allow determining the effects which targets characteristics have on the system's ability to acquire them.

6.4.5 Flight Procedures (Substitute laser system).

Analyze the test data to determine under what test conditions one system had functional advantage over the other and when the systems performed comparably.

6.4.6 General

a. The remainder of the data will be summarized as appropriate. Photographic records will be positively identified. The total data will be analyzed to determine to what degree the laser system and its maintenance package meet the requirements of QMR's, SDR's, TC's, and detailed military specifications. Record all shortcomings or deficiencies.

b. The data will also be further analyzed, where appropriate, to determine the extent to which the system under test exceeds the performance characteristics or otherwise provides distinct advantages over existing Army equipment providing for the same requirements. Provide a recommendation as to the suitability of the laser system and its maintenance test package for use by the Army.

APPENDIX A

Personnel Precautions in Laser Operations

The following general precautions and procedures for personnel involved in laser operations have been extracted from TB MED 279. For more specific information, consult this reference.

1. Exposure control. Control of occupational hazards incidental to the use of lasers is necessary for protection of personnel from exposures which may damage the eye, the most likely part of the body to be injured. Potential occupational hazards also include: burns from contact with liquid nitrogen or other substances used as coolants; electrical shock; exposure to gases such as ozone; and explosions of capacitor banks, optical pumps system, and target materials. Standard Operating Procedures (SOP) must be prepared, maintained, and enforced for the protection of both operating personnel and such other persons as may be required to be present at laser installations. Suitable control should be provided as indicated by the nature of the operation.

   a. General Precautions Applicable to All Laser Installations.

   (1) Avoid aligning the laser with the naked eye to prevent looking along the axis of the beam.

   (2) Looking into the primary beam must be avoided and equal care should be exerted to avoid looking at specular reflections of the beam, including those from lens surfaces.

   (3) Work with lasers should be done in areas of high general illumination, except where this would severely impair mission accomplishment.

   (4) The laser beam should be discharged into a background that is non-reflective and fire resistant.

   (5) An area should be cleared of personnel for a reasonable distance on all sides of the anticipated path of the laser beam.

   (6) Suitable precautions to avoid electrical shock should be followed in connection with the potentially dangerous electrical circuits (both high and low voltage).

   (7) Safety eyewear of an appropriate optical density should be worn during the firing of a laser. Safety eyewear designed to filter out the specific frequencies characteristic of the system affords adequate protection only if properly designed and utilized. This protective eyewear should be appropriately labelled to indicate the optical density at specific wavelength(s) and should be inspected periodically to insure physical integrity and proper labelling. There should be assurance that safety eyewear designed for specific lasers are not mistakenly used with lasers of different wavelength.

b. Precautions for Lasers in an Outdoor Environment.

(1) Personnel should be excluded from the beam path to a distance where power or energy density is within permissible levels. This may be accomplished by the use of physical barriers, administrative control, interlocks, and limiting beam traverse.

(2) The inadvertent or intentional tracking of non-target vehicular traffic or aircraft should be prohibited if within calculated hazardous distance.

(3) Operation of the laser in rain, snow, fog, or dust necessitates the use of protective equipment.

(4) The beam path should be void of all objects capable of producing potentially hazardous reflections.

2. Personnel protective equipment.

a. Personnel whose occupation or assignment require exposure to laser beams should be furnished through local procurement supply channels, suitable laser safety goggles which will protect for the specific wavelength of the laser and be of optical density (O.D.) adequate for the energy involved. Table I lists the maximum power or energy density for which adequate protection is afforded by glasses of optical densities from 1 through 8.

Table I. Selecting Laser Safety Glass

Intensity			Attenutation		
Q-switch maximum energy density (j/cm^2)	Non-Q-switch maximum energy density (j/cm^2)	CW maximum power density (watts/cm^2)	Optical density (O.D.)	Decibel (db) attenuation	Attenuation factor
10^{-7}	10^{-6}	10^{-6}	1	10	10
10^{-6}	10^{-5}	10^{-5}	2	20	10^2
10^{-5}	10^{-4}	10^{-4}	3	30	10^3
10^{-4}	10^{-3}	10^{-3}	4	40	10^4
10^{-3}	10^{-2}	10^{-2}	5	50	10^5
10^{-2}	10^{-1}	10^{-1}	6	60	10^6
10^{-1}	1.0	1.0	7	70	10^7
1.0	10.0	10.0	8	80	10^8

b. Needless exposure of the skin of personnel should be avoided; exposure of the skin above should not exceed 10^5 times authorized energy density levels and should not exceed 100 mw/cm^2 for CO_2 lasers. When the hands or other parts of the body must be exposed, protective coverings, gloves, or shields must be used. The face should be turned away from the target area. Laser welding facilities should have sufficient shielding surrounding the article being welded.

c. Impervious, quick removal gloves, face shields, and safety glasses should be provided as protection for personnel who handle the extremely low temperature liquid coolants which may be used in higher powered lasers.

3. Medical surveillance. An individual whose occupation or assignment may result in exposure to laser radiation shall have a preplacement medical examination, a termination of employment examination, and be included in an occupational vision program which encompasses thorough general

ophthalmologic examinations at regular intervals. Such examinations shall include fundoscopic studies and will give consideration to slit lamp examinations, mapping of the visual fields, and ophthalmologically evaluated retinal photographs or drawings of the foveal area, as indicated. Periodic eye examinations are recommended at 6- or 12-month intervals, depending upon extent of exposure, or at such other times as there may be reason to believe that eye damage from laser may have occurred. For individuals exposed to lasers emitting radiation in the ultraviolet and infrared regions, it is advisable to do a slit lamp examination periodically.

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13. ABSTRACT

Procedures are described for evaluating the suitability of airborne laser systems for Army use. Laser applications, including terrain mapping, range finding, communication, and fire control, are discussed. Laser system safety considerations are given detailed treatment.

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